

Accelerator Status, Expected Performance, PIP

R. Dixon

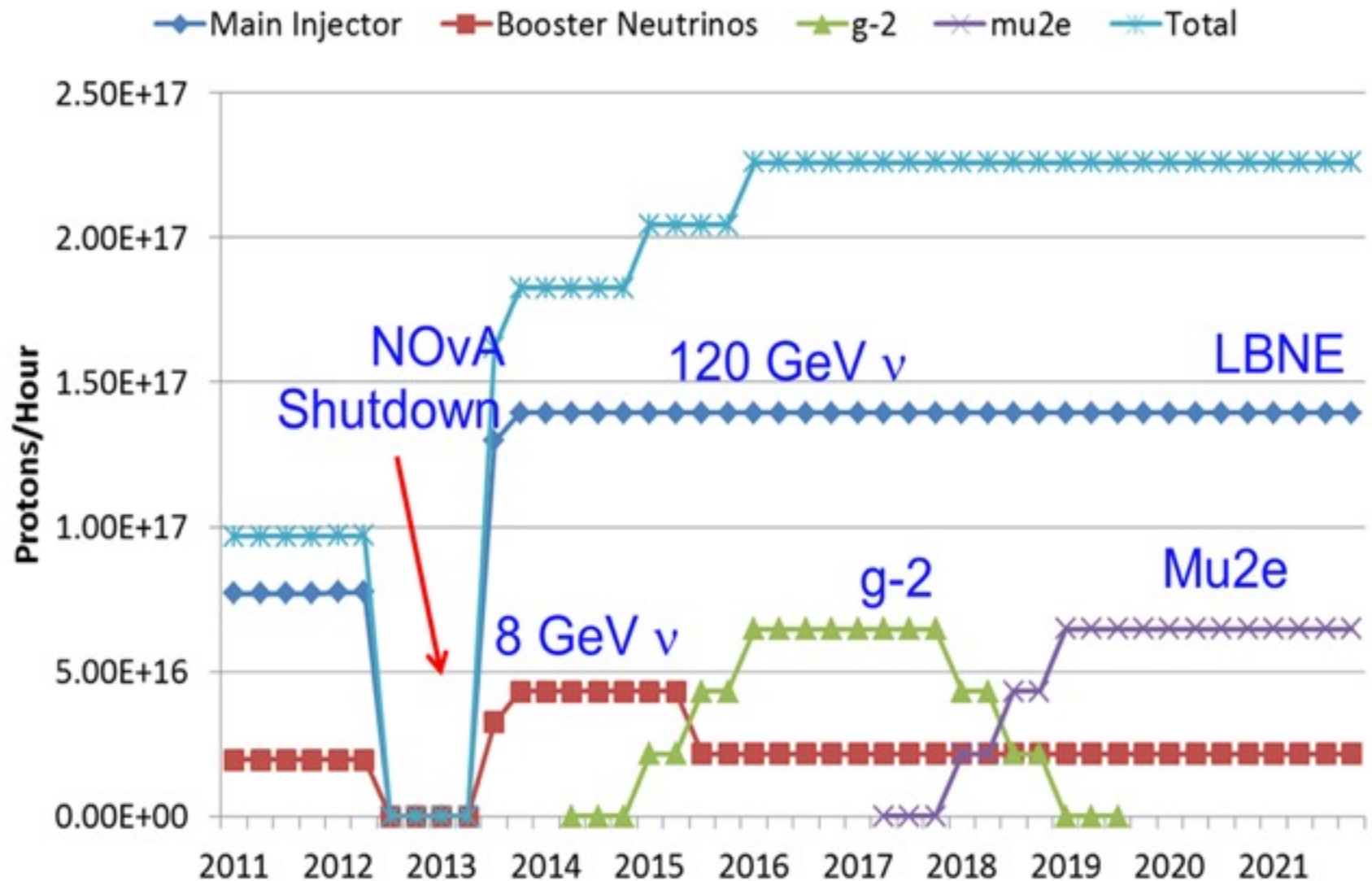
Overview

- Summary of Shutdown Work
 - Proton Improvement Plan Work and Status
 - Main Injector/Recycler Work and Status
 - NuMI Beam Changes
- Startup Plan and Issues
- Expected Performance



Monday, June 3, 2013

Future Proton Needs



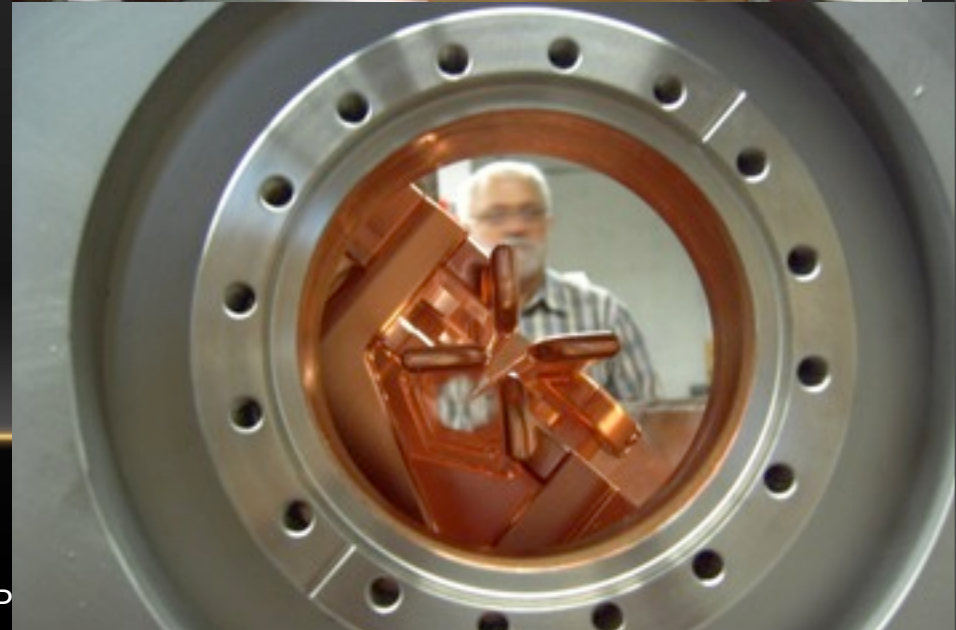
Proton Improvement Plan

- Proton source is 40 years old
 - Must run for at least 15 more years to support lab physics program
- Need upgrades to permit higher rep rate for intensity frontier
- Identify weaknesses and remedy
 - Cockcroft-Waltons
 - (2009 I- off for ~ 1 year for repair)
 - Solution – RFQ Based Injector
 - Install this shutdown



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Fermilab P

Major Shutdown Jobs in Linac

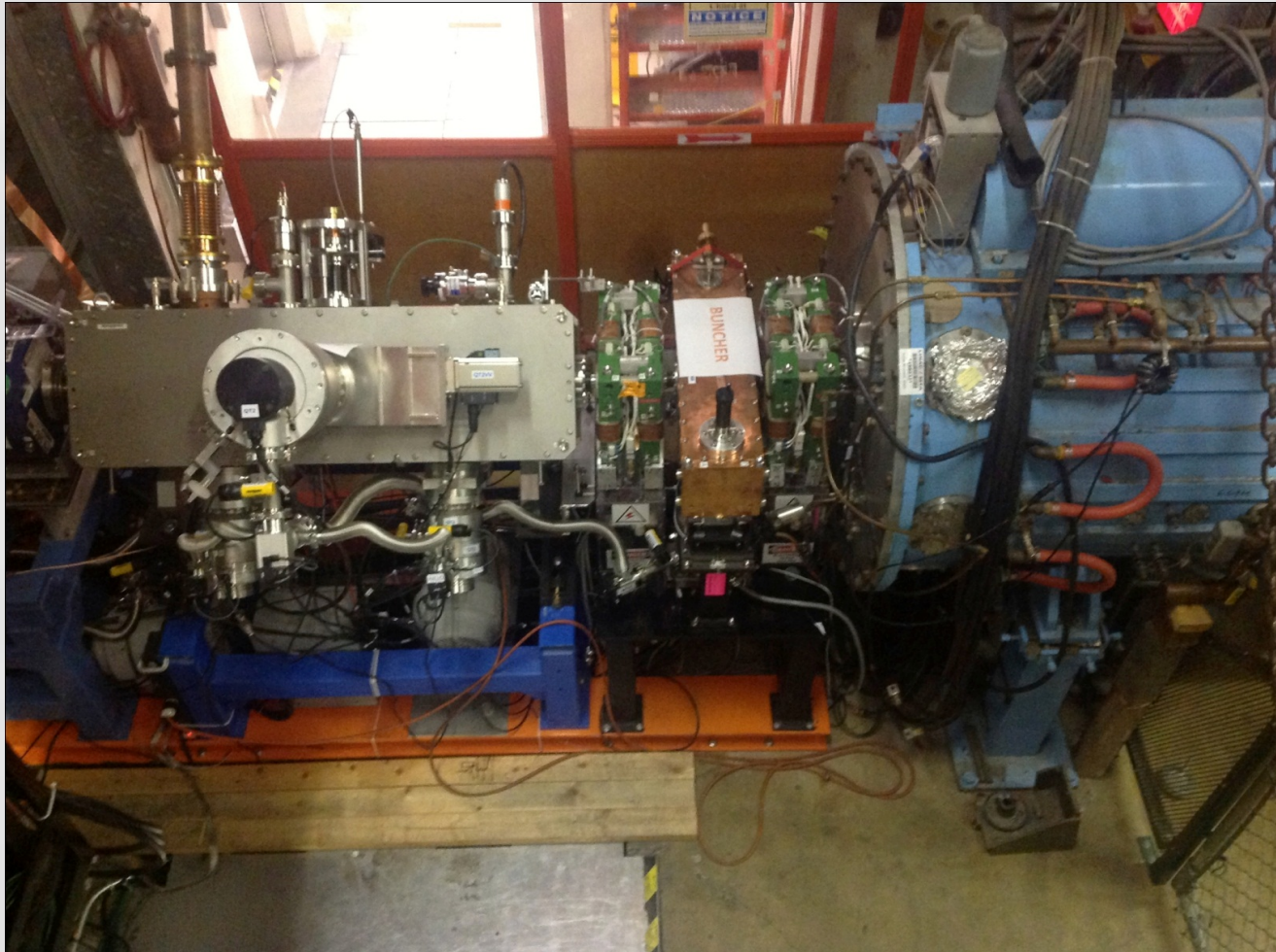
- Pre-Acc
 - RFQ Injector Upgrade!!!
- Linac
 - Linac Dump Repair
 - Vacuum Upgrades
 - BPM Upgrade
 - Klystron Maintenance
 - Low Energy Maintenance
 - Improve MTA beam
 - Run NTF
- Also Investigating Low Energy Modulators

Proton Improvement Plan

- Linac
 - Linac Dump Repair
 - Vacuum Upgrades
 - BPM Upgrade
 - Klystron Maintenance
 - Low Energy Maintenance
- Booster
 - Solid State Upgrade
 - Booster Cavity Refurb.
 - Gradient Magnet Moves
 - Beam Absorber Install
 - LCW Upgrade
 - Possible Shielding Changes



RFQ and MEBT



The H- injector



page 2

PMG May 2013

 **Fermilab**

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RFQ injector status

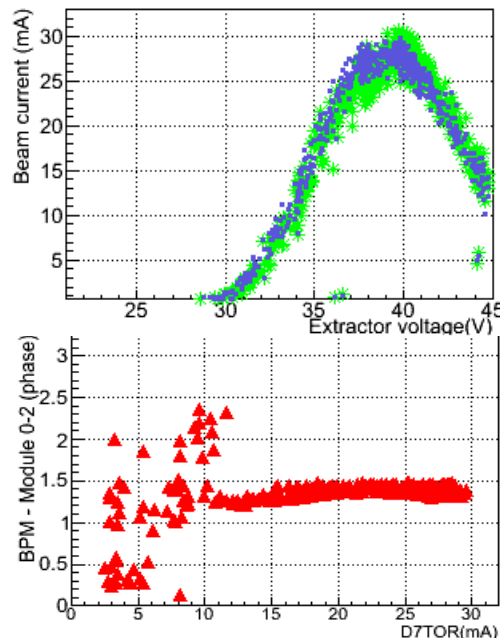
- Injector is basically done
 - In operation since end of 2012.
- There are still a few problems that need to addressed
 - These are not showstoppers.

Linac Instrumentation

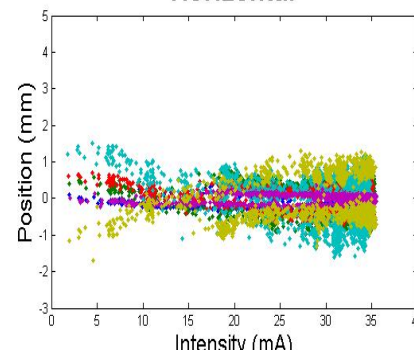
- BPM Electronics Upgrade complete

- ▶ Update existing RF Logamp electronics with Digital electronics
 - ▶ FPGA, ADC, Digital Signal Processing
 - ▶ Long term stability
 - ▶ Flexibility to modify system as needed

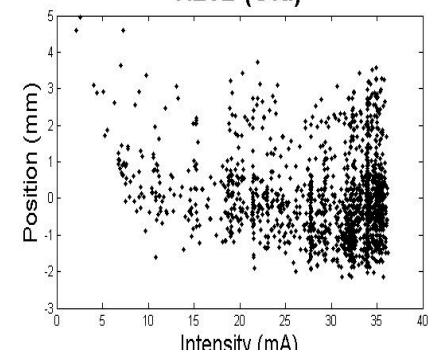
Diagnostics Room



Horizontal



H202 (Old)

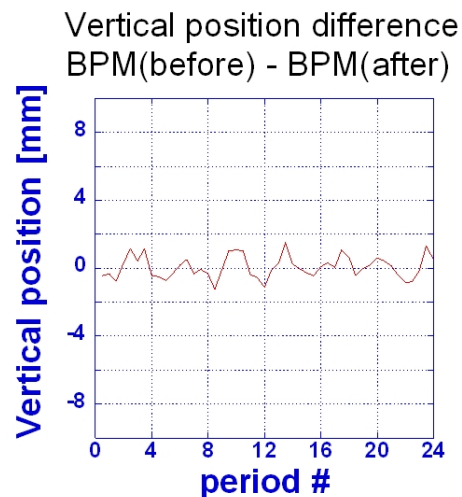


Major Shutdown Jobs in Booster

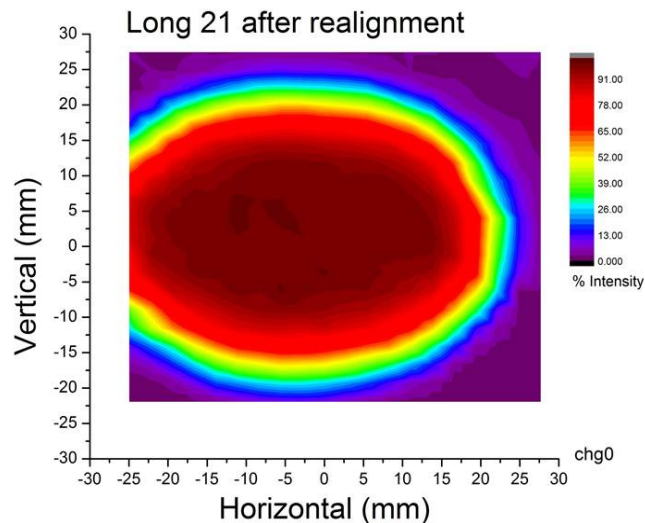
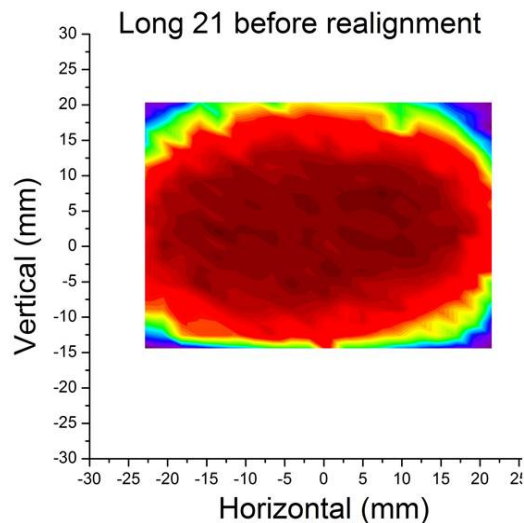
- Solid State Upgrade
- Booster Cavity Refurbishment
 - Needed for 15 Hz operation
- Gradient Magnet Moves
- Beam Absorber Install
- LCW Upgrade
- Possible Shielding Changes

Booster Magnet Alignment

Measurements



Difference of the measured orbit between before and after a magnet move



Measured aperture before (left) and after (right) the magnet realignment.

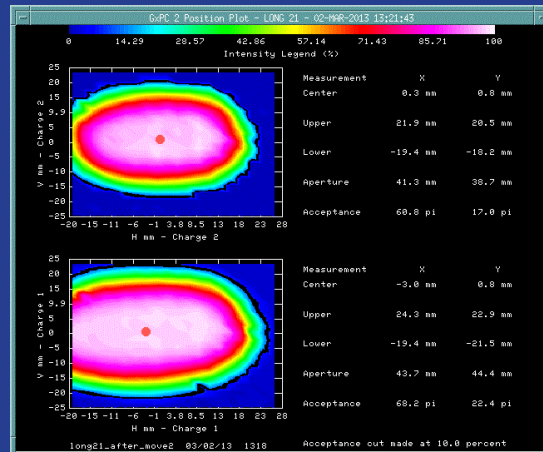
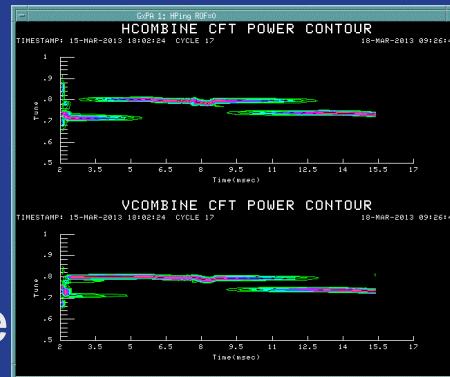
WBS 1.2.2 Accelerator Physics (Booster)

• WBS 1.2.2.1 Simulations and Studies

- Beta corrections
- Chromaticity
- Tunes
- Software / Lattice

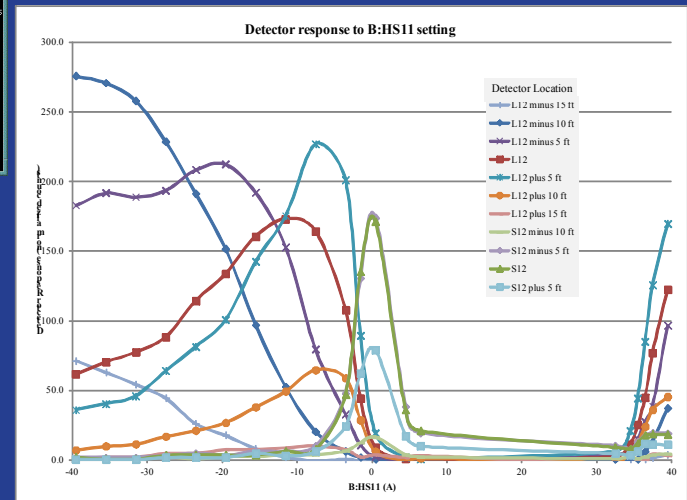
• WBS 1.2.2.2 Alignment & Aperture

- Magnet moves
- Scans



• WBS 1.2.2.6 Radiation Shielding

- Long Straights Completed



Cavity Refurbishment

There is always something unexpected: goop epoxy fix from some prior leak



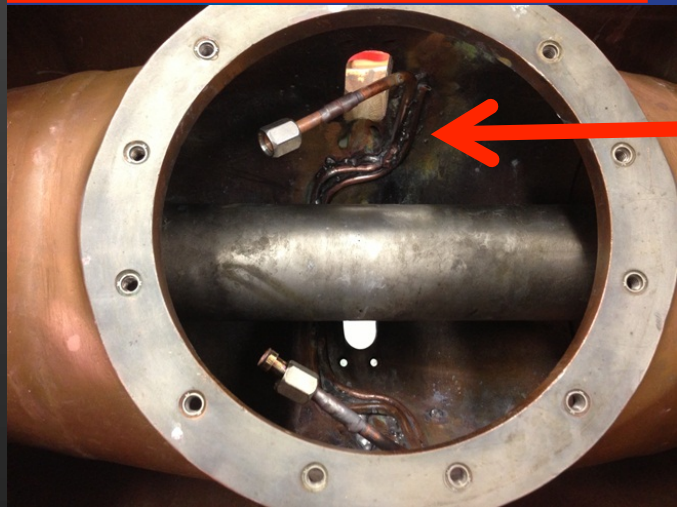
Gollwitzer AEM

11

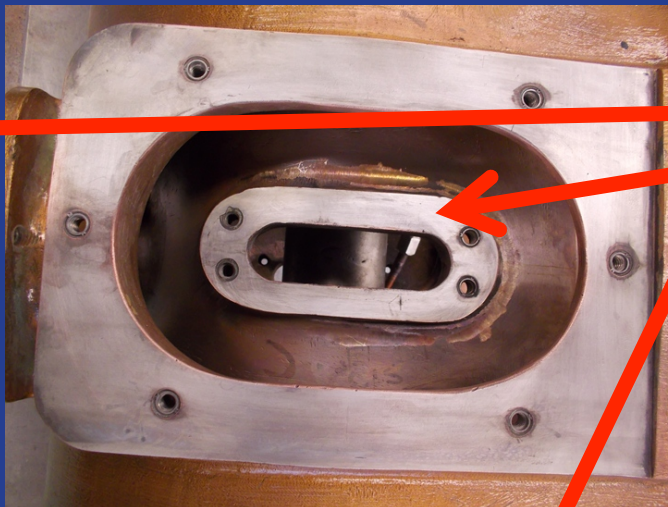
WBS 1.2 Booster (Highlights)

WBS 1.2.1.5 Cavity Refurbishment

New cooling line on cavity #1007

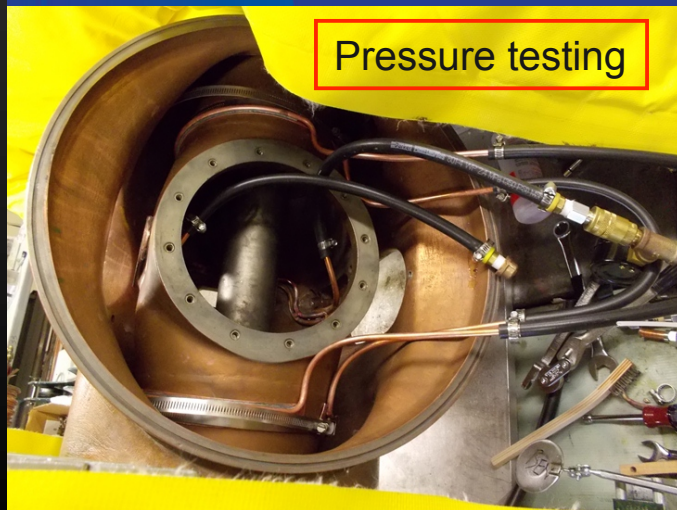


Repaired flange surface



#1007 Issues:
Water Leaks
RF heating
RF leaks
Activation

Pressure testing



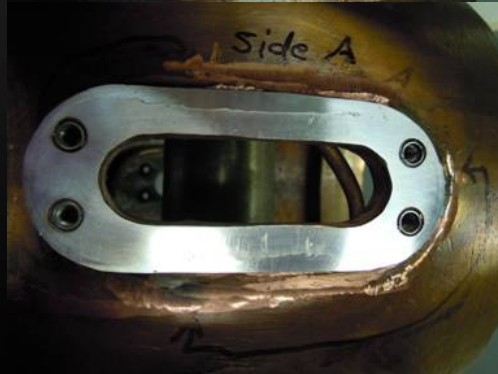
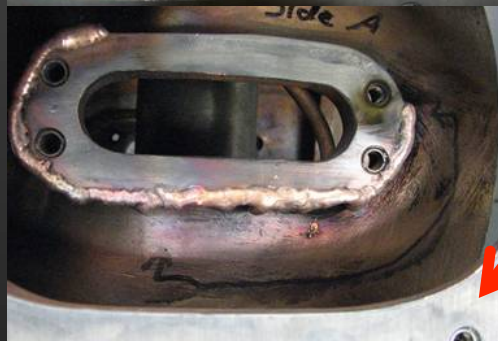
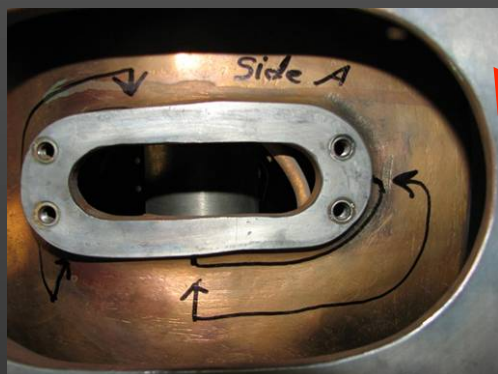
Bottom tuner connected

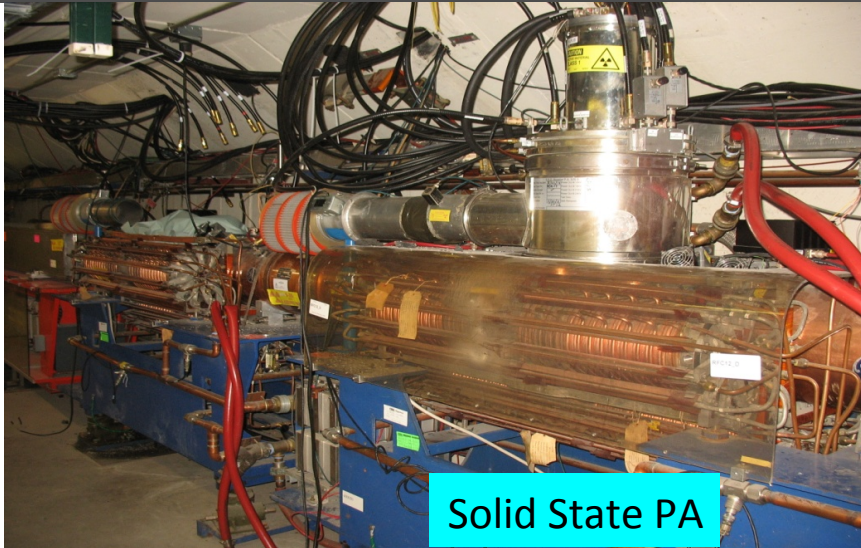


RF leak from outer flange?

We are now concerned about connection with outer flange

Pulled one cavity and have started testing





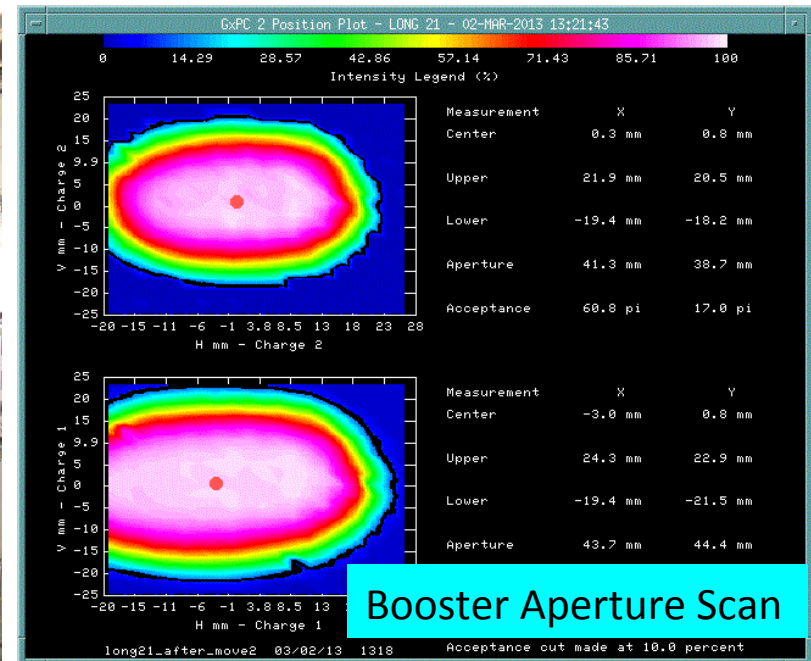
Solid State PA



Booster Notch Beam Absorber

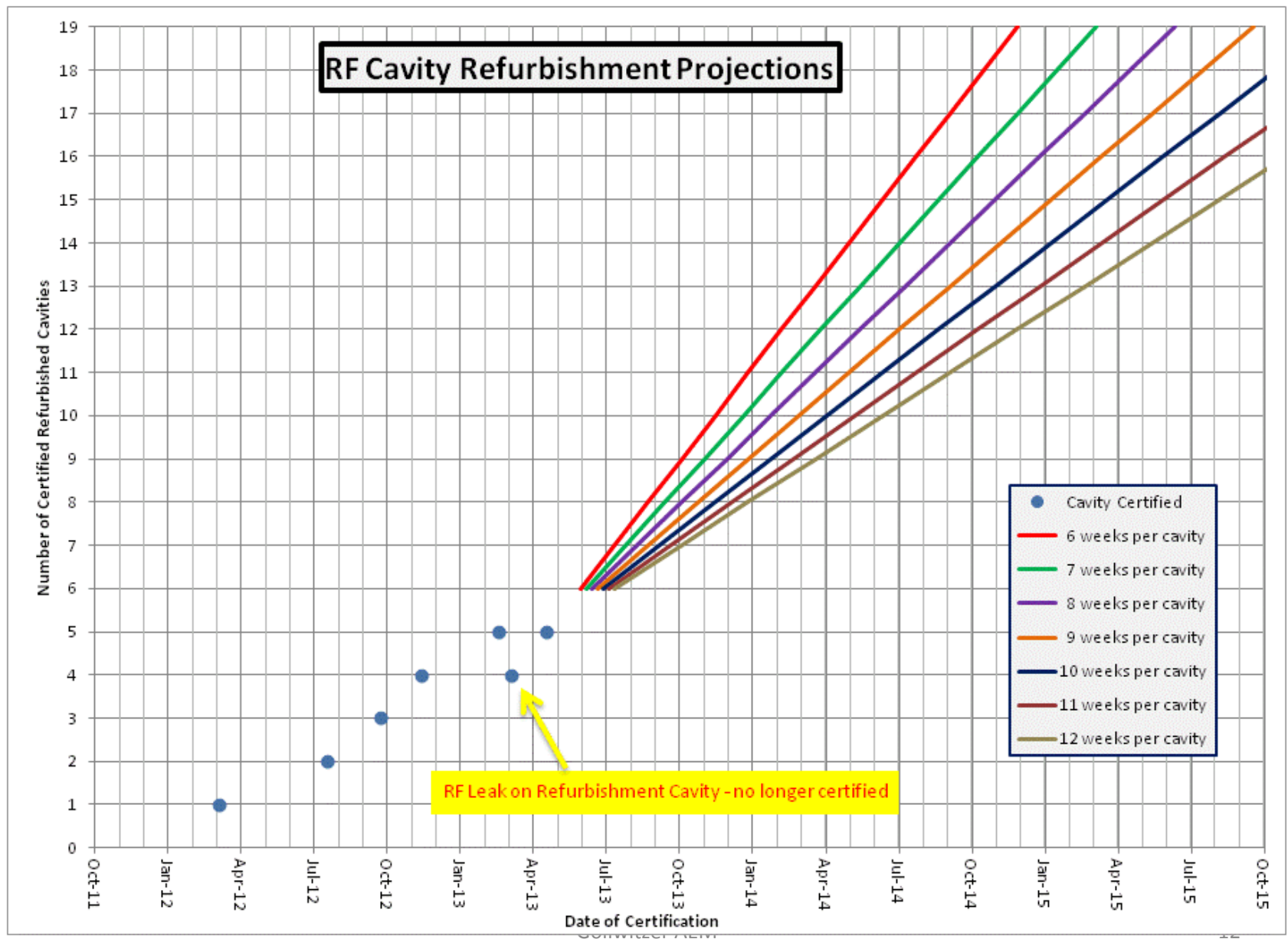


Booster Solid State RF Station



Booster Aperture Scan

Bill Pellico NOvA



PIP Work Update

- Injector (RFQ)
 - RFQ injector installed
 - Nov FY13
 - Operations Dec FY13
 - Hardware/ Beam Studies Continue
- Linac
 - Beam established Nov FY13
 - Beam physics – matching
 - Match to RFQ injector
 - Working on lattice/software
 - New BPM/Toroid electronics
 - Upgraded vacuum systems
- Booster
 - New beam absorber
 - 19,000 lbs of steel & concrete for dump of notched beam
 - 3 kicker systems configured
 - Solid State Completed
 - New Modulators
 - New Power Amplifiers (PA)
 - New Solid State drivers
 - Controls and Cabling
 - Magnet/orbit Corrections
 - Beam physics - Lattice Corrections
 - Upgraded LCW system
 - Refurbishment of RF Cavities
 - 6 of 19 completed

Bill Pellico NOvA

Beam Status

- RFQ injector largely in operations mode
 - Still adjusting new sources
 - Beam current at ~ 30ma but design is for 35ma
 - Second Source – with some improved hardware/design being tested
 - Additional trim package being added in May - should help increase beam current
- Linac Commissioning continues
 - Efficiency improved with new injector
 - Still lower current than before shutdown – but improving
 - Before MI starts up – will have to work on two week stations (saving tubes)
- Booster beam up and running
 - Beam at half of desired (pre-shutdown) levels
 - Work on RF systems (Refurbishment) limits beam current due to lower voltage
 - New orbits/operating point being studied
 - Still working on RF systems – commissioning – debugging
 - Refurbishment continues and will require stations out of the tunnel for repair – two more years
 - Beam shielding assessment still being worked on – should not prevent operations

Bill Pellico NOvA

Near Term Plans

- RFQ injector – Will be adding a new trim package (improve transmission)
- Installing Booster Utility Transformer
- Installing Linac Roof access
- Booster aperture studies
- Booster Cogging studies
- Booster Lattice Studies
- Booster Cavity Refurbishment

- Operations:
 - Higher Intensity Tune-up
 - Address shielding assessment issues to allow for higher flux

Accelerator (ANU) and NuMI Upgrades

- Recycler Ring, RR
 - New injection line into RR
 - New extraction line from RR
 - New 53 MHz RF system
 - Instrumentation Upgrades
 - New abort kickers
 - Decommissioning of pbar components
- Main Injector
 - Two 53 MHz cavities
 - Quad Power Supply Upgrade
 - Low Level RF System
- NuMI
 - Change to medium energy ν beam configuration (new target, horn, configuration)
 - Cooling & power supply upgrades



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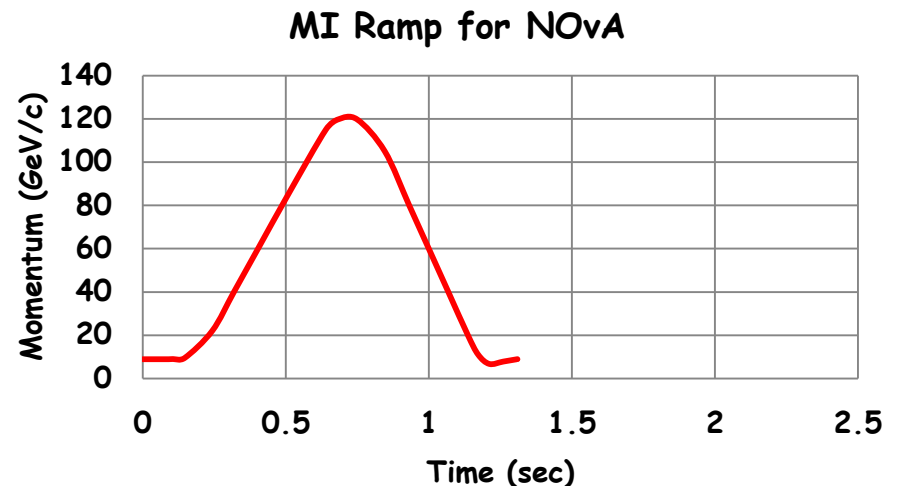
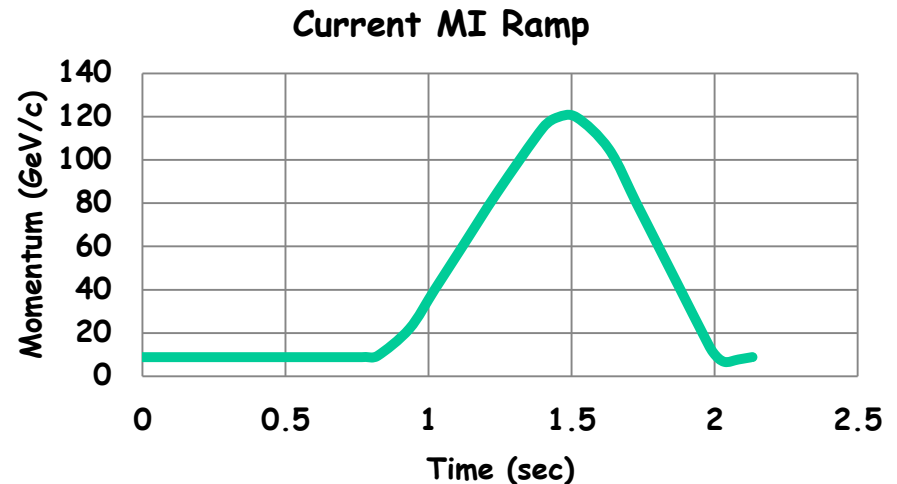
Installation Shutdown

- 12 months to change over to new mode of operations
 - Removing all pbar hardware
 - About 100 magnets, 8 cooling tanks, 2 beamlines, diagnostics for storage rings
 - Installing more than 150 magnets (dipoles, quads, trims, kickers, lambertsons)
 - Pulling nearly 400,000 feet of cable (including 300,000 ft of 3/8" heliax)
 - 2 cables to every BPM in the Recycler
 - 5 RF cavities (2 to MI, 3 to RR)
 - Opening 11 RR vacuum sectors – all of which require baking to recover 10^{-10} vacuum level
 - Alignment of new components and areas where components are removed
 - 1 target carrier, 1 new horn
 - Moving Horn 2 and rearranging the shielding
 - Maintenance and upgrades for other programs extend the length from 10 months to 12 months
- Lots of people and equipment traffic!
 - 40+ technicians and engineering staff (Accelerator Division, Technical Division, and Particle Physics Division)
 - 40+ trades (pipefitters, riggers, electricians)
 - 1 equipment access point



MI Operation for NOvA

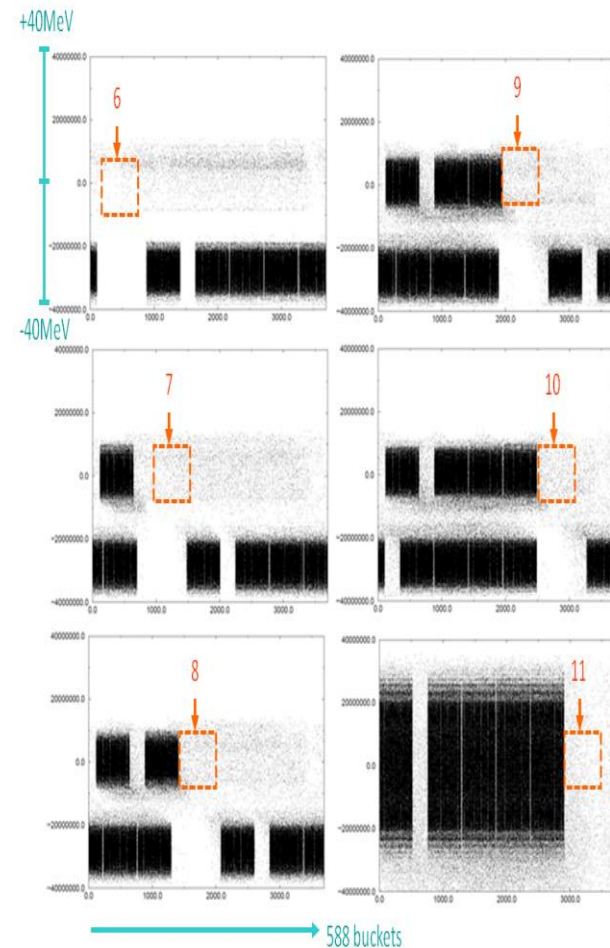
- MI Cycle Reduced from 2.2 sec (33 Booster Ticks) to 1.33 sec (20 Booster Ticks).
- MI Beam Intensity increased by 9% (per bunch intensity remains the same).
- No Instability Issues are anticipated.
- Loss control is the major Issue (Power loss is increased by 80%).





Gap Clearing Kickers

- A system of fast kickers (57 nsec rise/fall times) was built and installed in MI (2010).
- These kickers were used to clear any beam left in the injection gap during the slip stacking.
- After the kicker installation the losses at the injection area (MI104-MI106) disappeared and we were able to increase the MI power to 400KW.
- The kickers were moved to Recycler during the ANU shutdown.

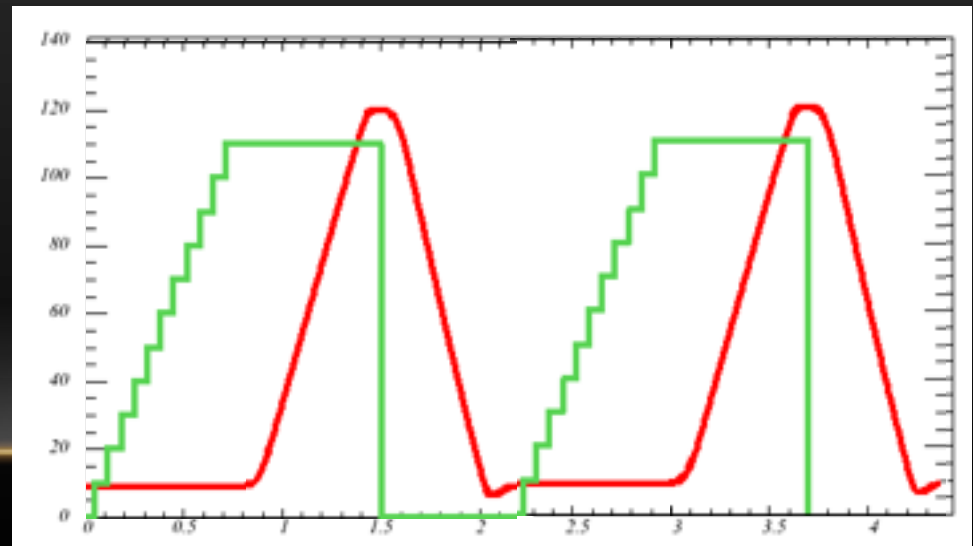


Slip Stacking Simulation showing beam left in the Injection Kicker Gap

Increasing beam power

Red: MI momentum

Green: Beam current

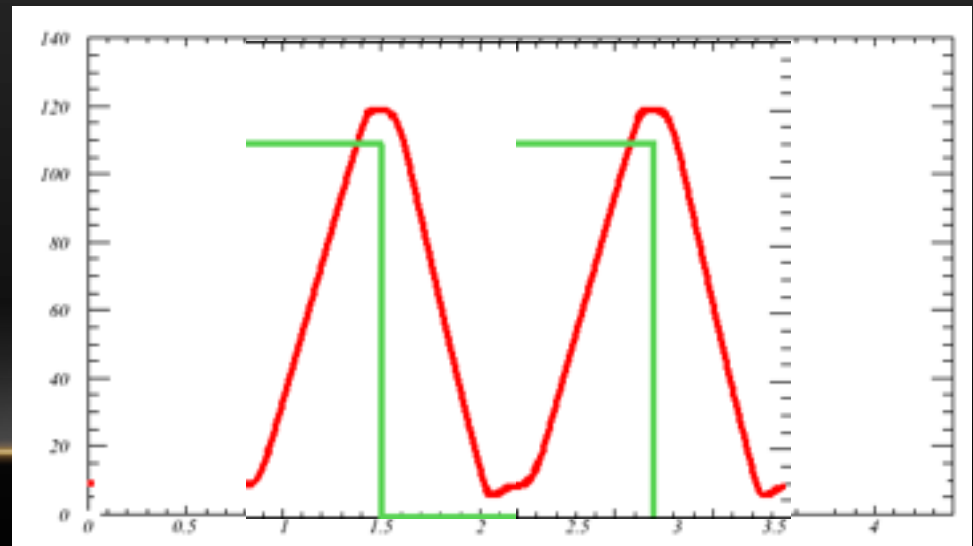
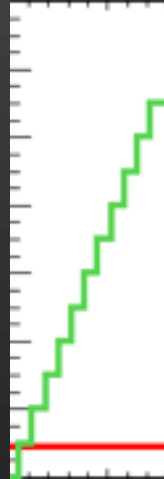


Recycler

Main Injector

Increasing beam power

Red: MI momentum
Green: Beam current

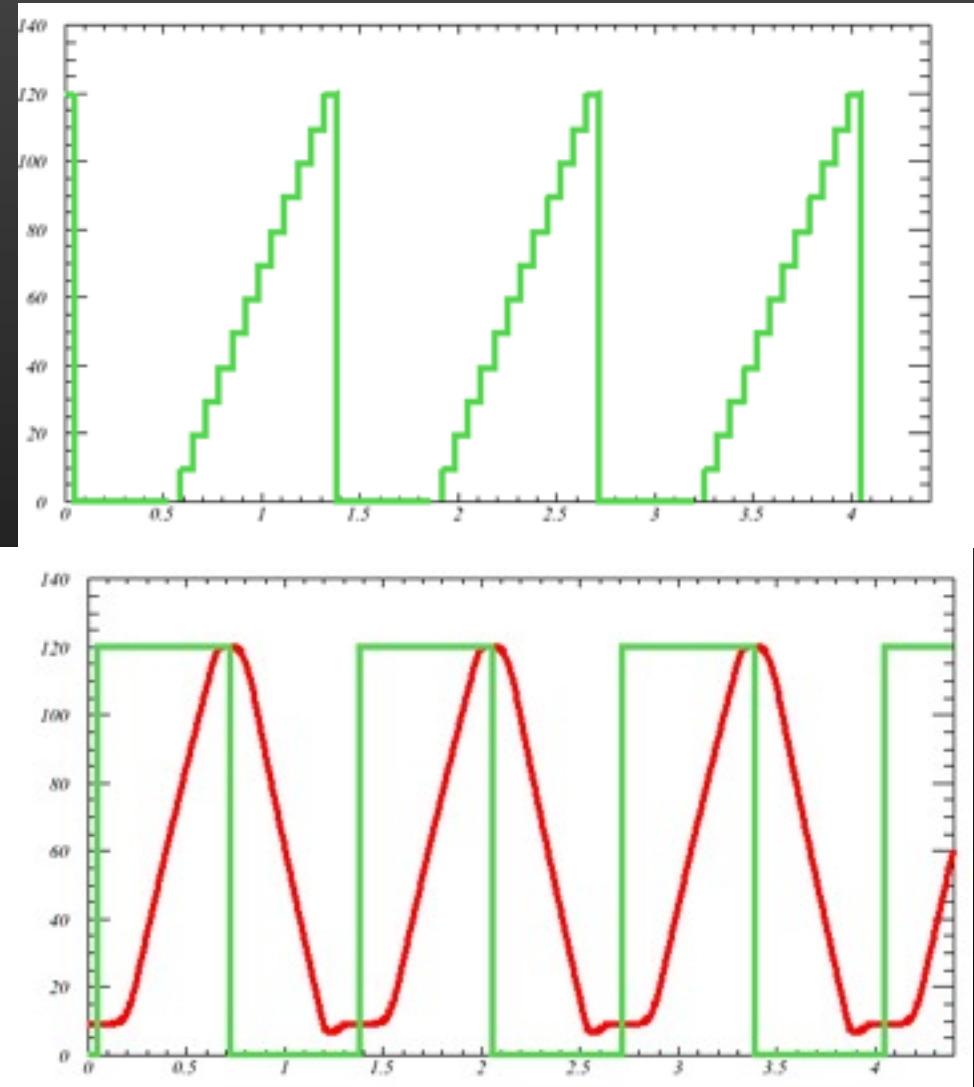


Recycler

Main Injector

Increasing beam power

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Recycler

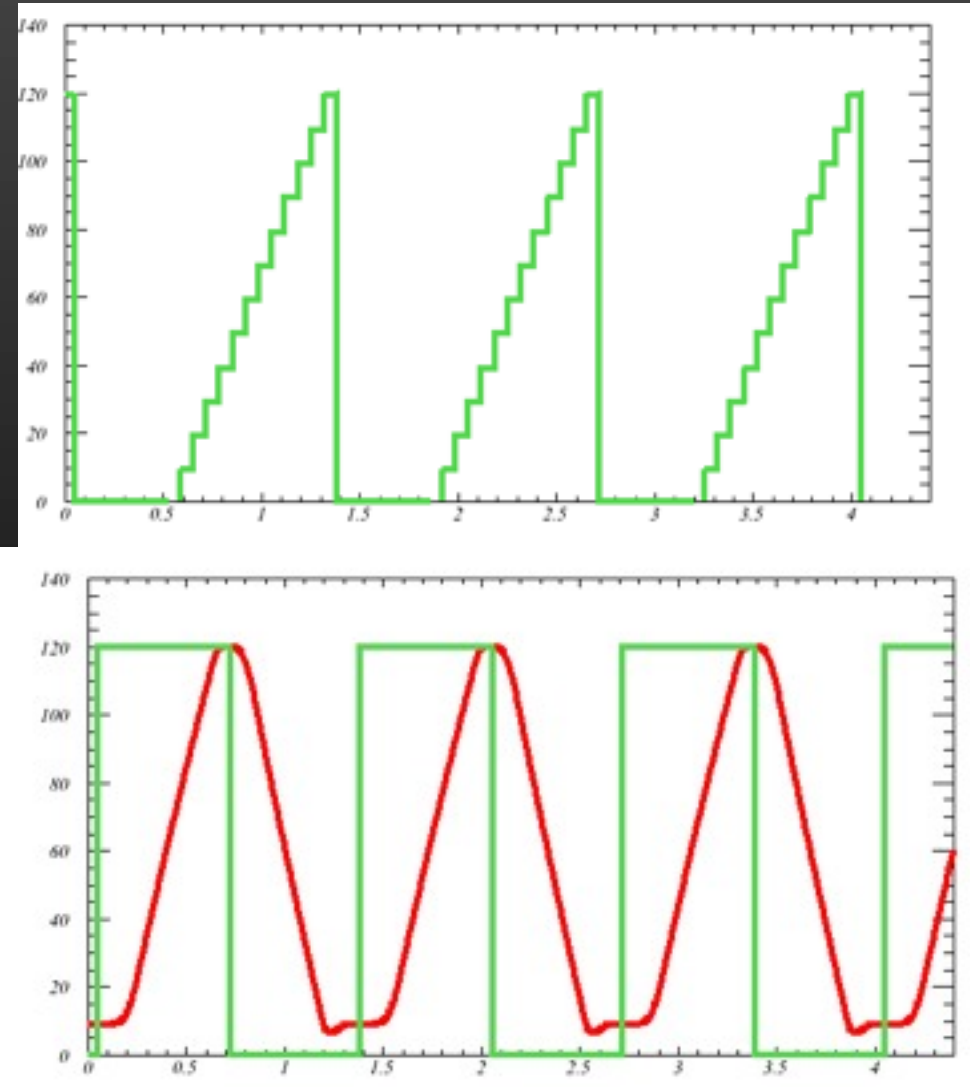
Main Injector

Increasing beam power

Red: MI momentum

Green: Beam current

- **Move slip-stacking to recycler**



Recycler

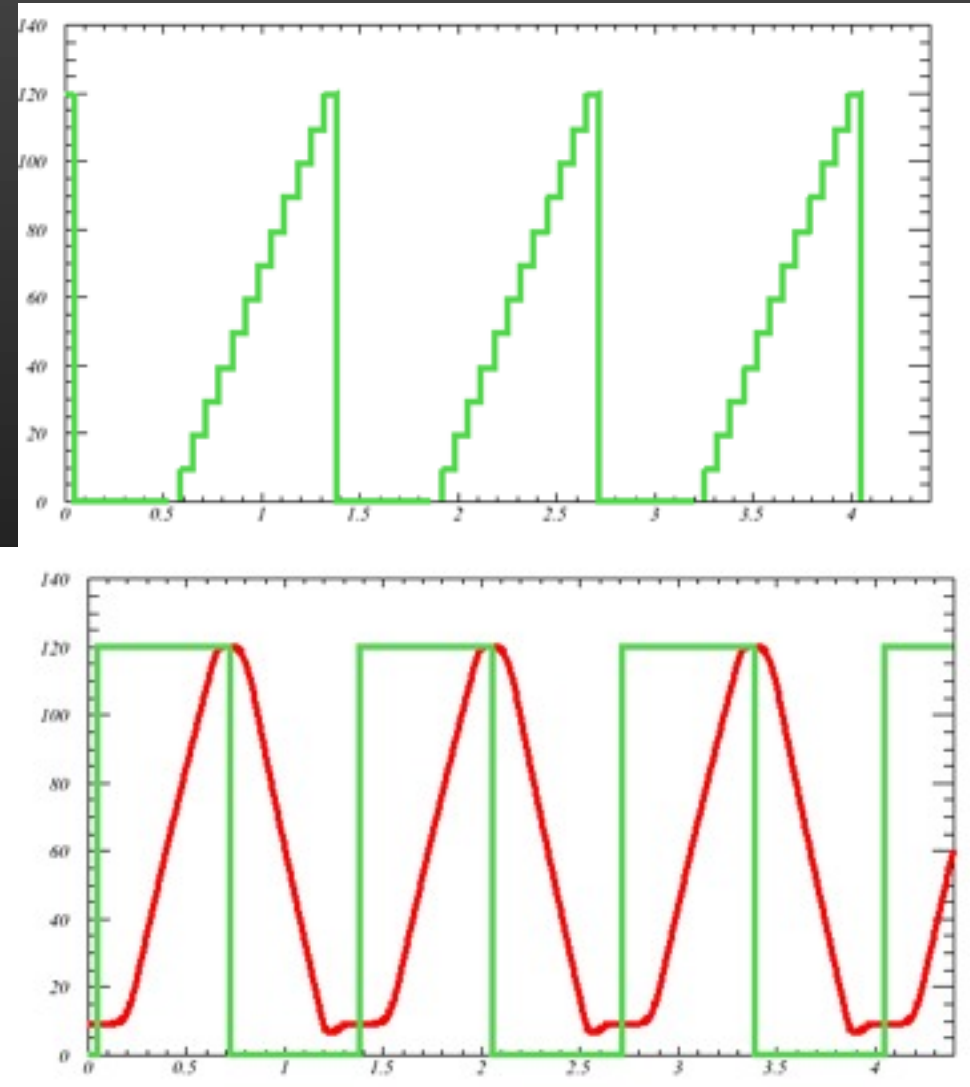
Main Injector

Increasing beam power

Red: MI momentum

Green: Beam current

- **Move slip-stacking to recycler**
- **11 batch -> 12 batch**



Recycler

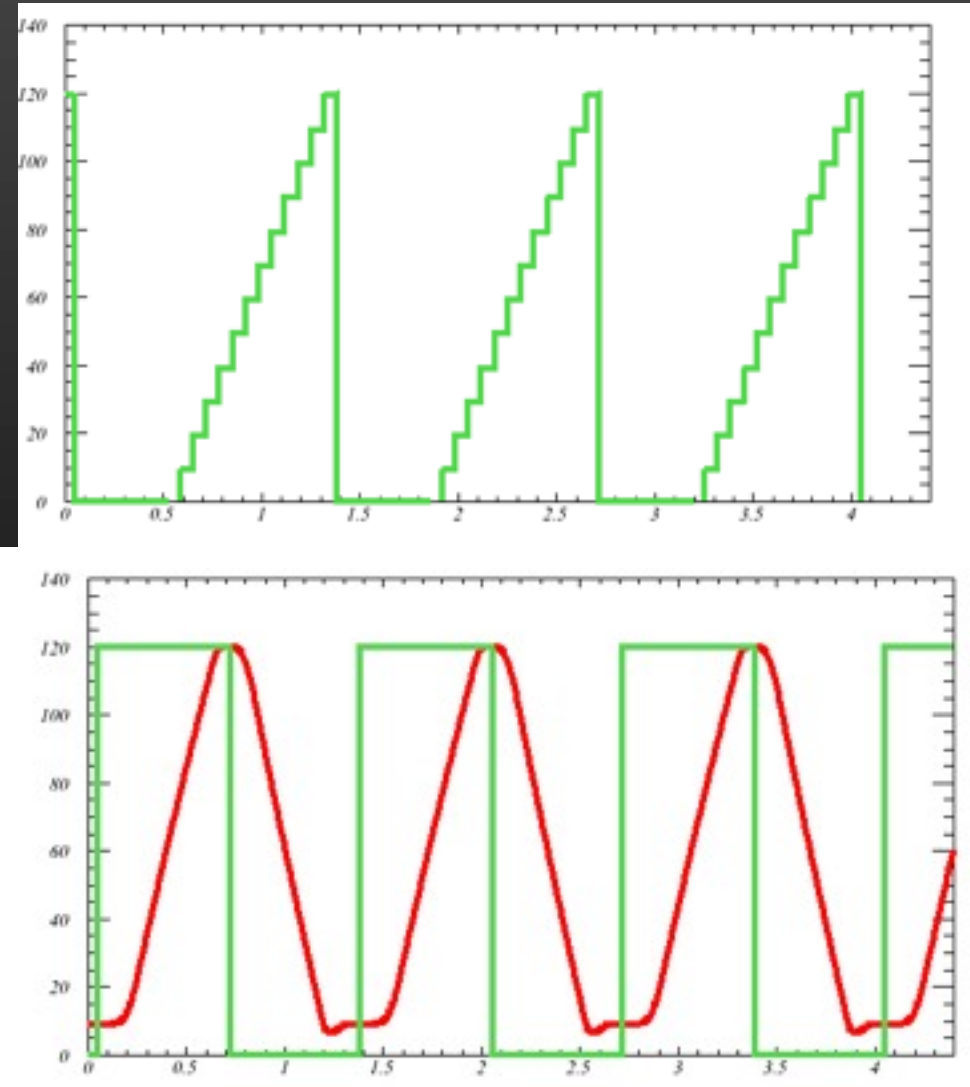
Main Injector

Increasing beam power

Red: MI momentum

Green: Beam current

- Move slip-stacking to recycler
- 11 batch -> 12 batch
- Increase Main Injector ramp rate (204 GeV/s -> 240 GeV/s)



Recycler

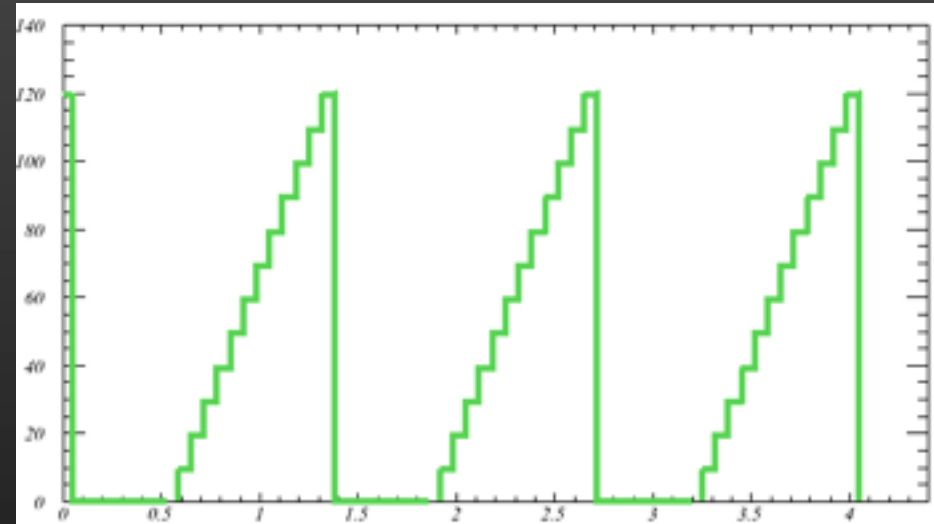
Main Injector

Increasing beam power

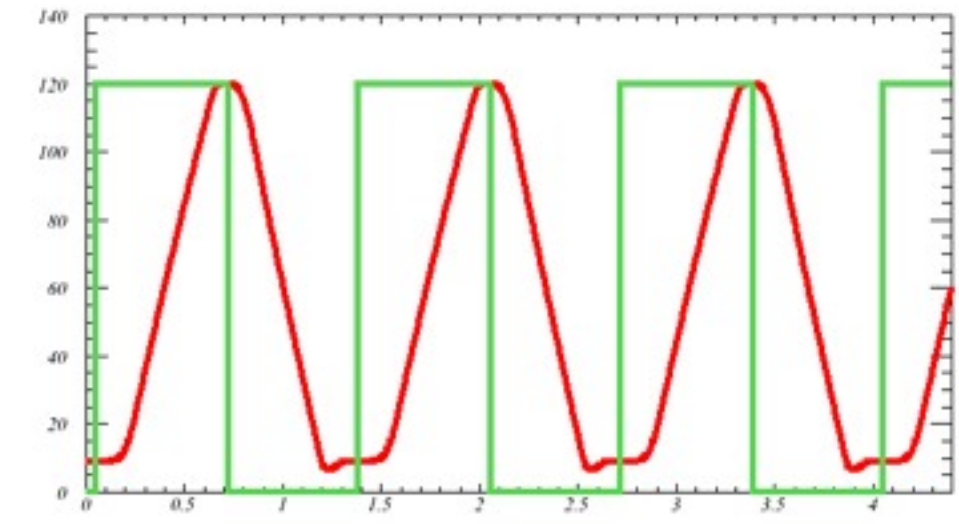
Red: MI momentum

Green: Beam current

- Move slip-stacking to recycler
- 11 batch -> 12 batch
- Increase Main Injector ramp rate (204 GeV/s -> 240 GeV/s)
- 330 (380) -> 700kW with only ~10% increase in per-pulse intensity



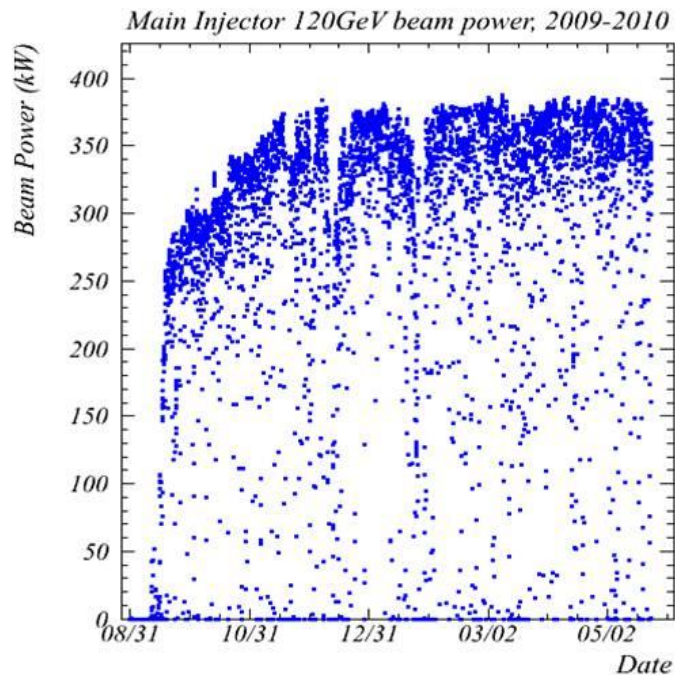
Recycler



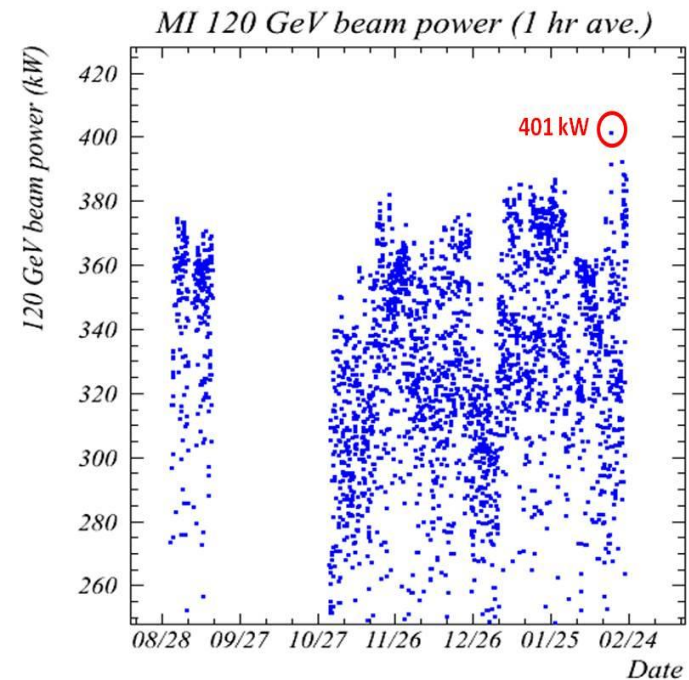
Main Injector



MI 120 GeV Beam Power



MI 120 GeV Beam Power 2009-2010



MI 120 GeV Beam Power 08/10-03/11

MI/RR Shutdown 2012



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Recycler Injection

June 3 – June 9



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Recycler Injection



Recycler Injection, MI, BNB



MI/RR Shutdown 2012

March 20th

Injection:

- Continue with re-assembling the Recycler-8 line vacuum from 848 to RR ring

Assembling beam pipe
to leak check MI and
RR injection lines from
846 through 852



MI-60 Girder Fabrication

- Staging complete assembly in MVA/MI-62 prior to shipping to MI-30
 - 8 girders are complete
 - Should be completed by the end of the Month



MI/RR Shutdown 2012

March 28th

RR-30 straight:

- Remaining Off project work
 - Vacuum Leaks in the MI 301 beam pipe



MI/RR Shutdown 2012

May 17th

MI 52 Lambertson:

Leak checks complete.

Bake-out set up complete.

Bake delayed due to equipment moves and electrical disconnect failure





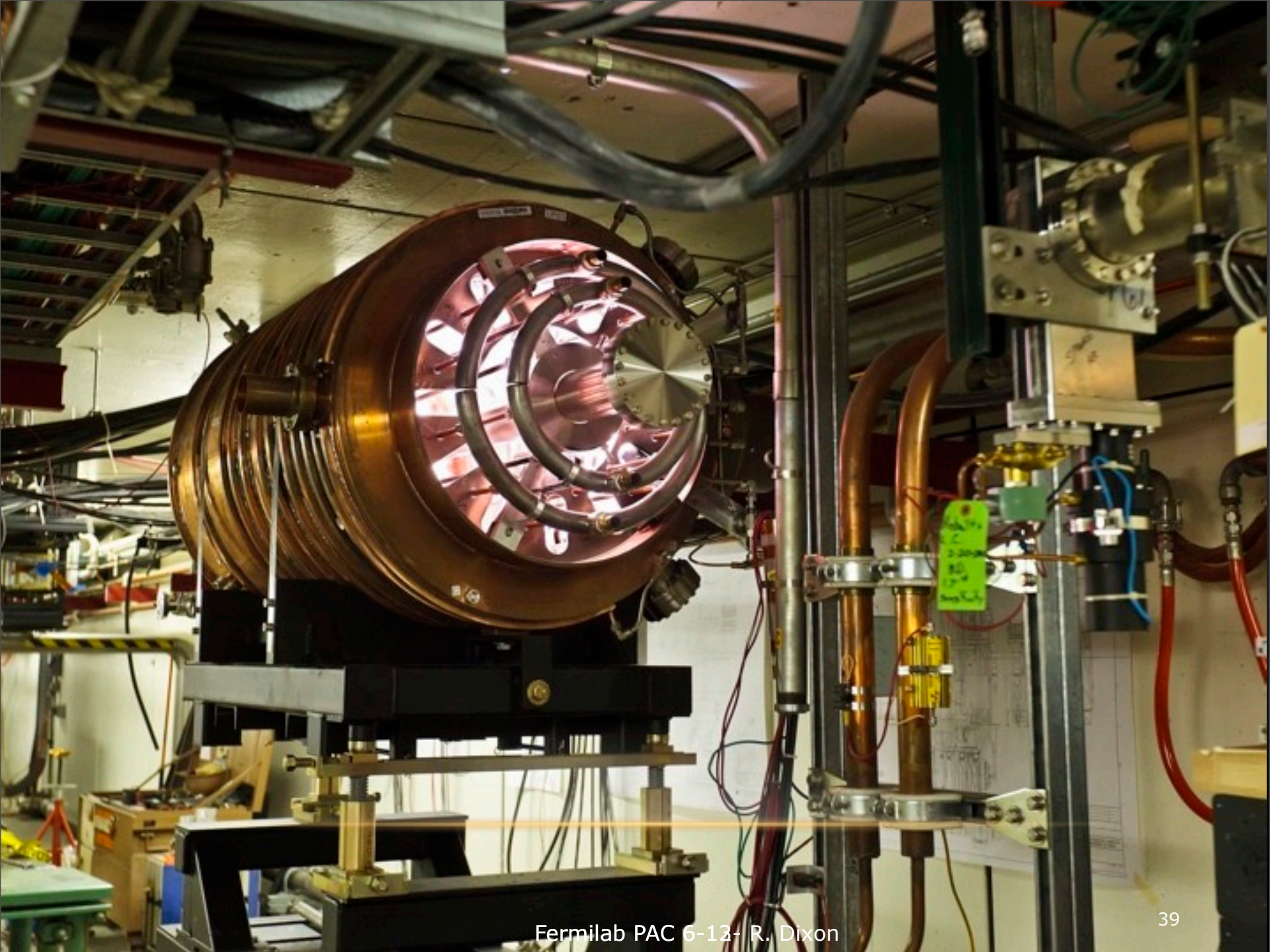
RR Injection Line Multi-Wire Cans



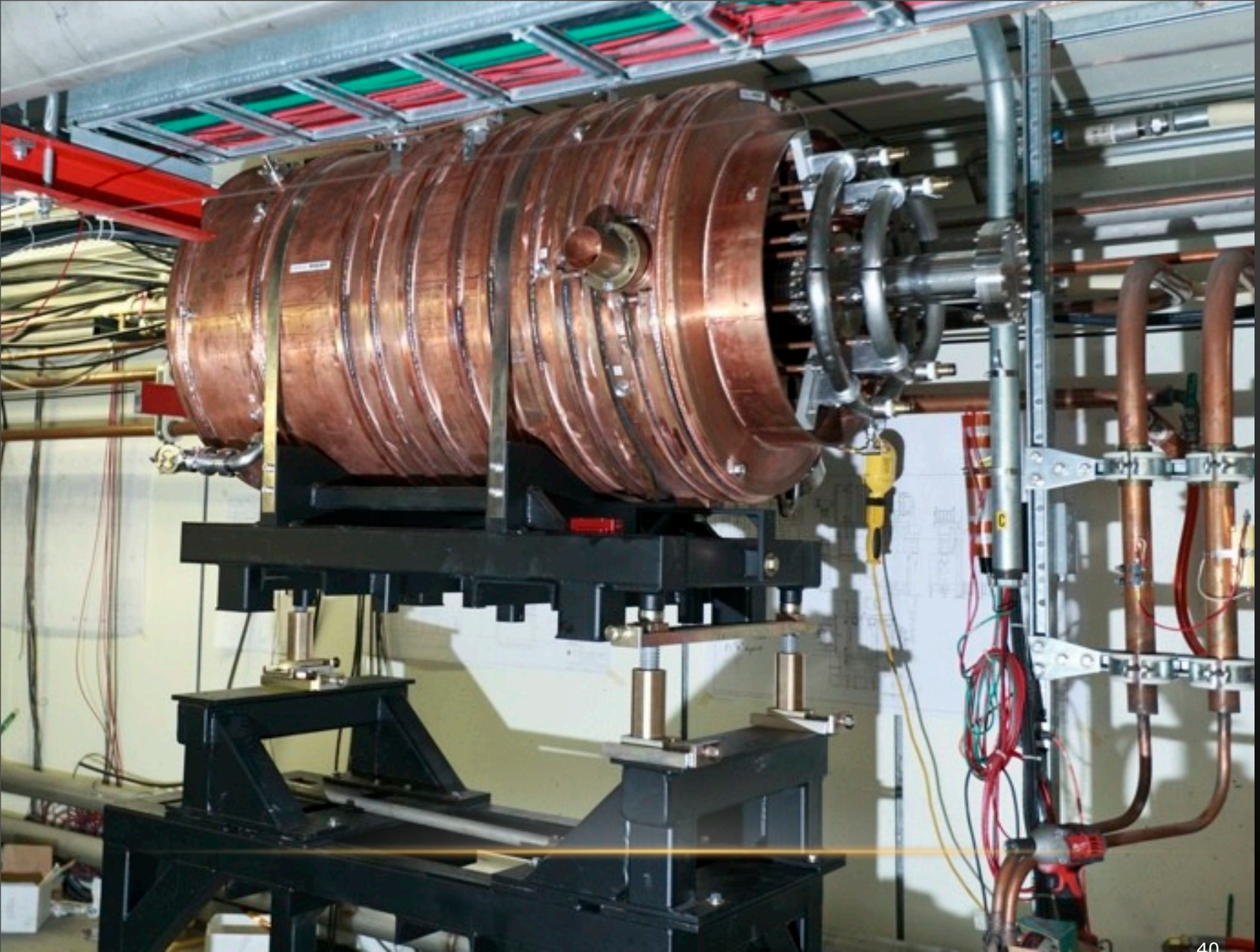


RR 40 kicker Installation





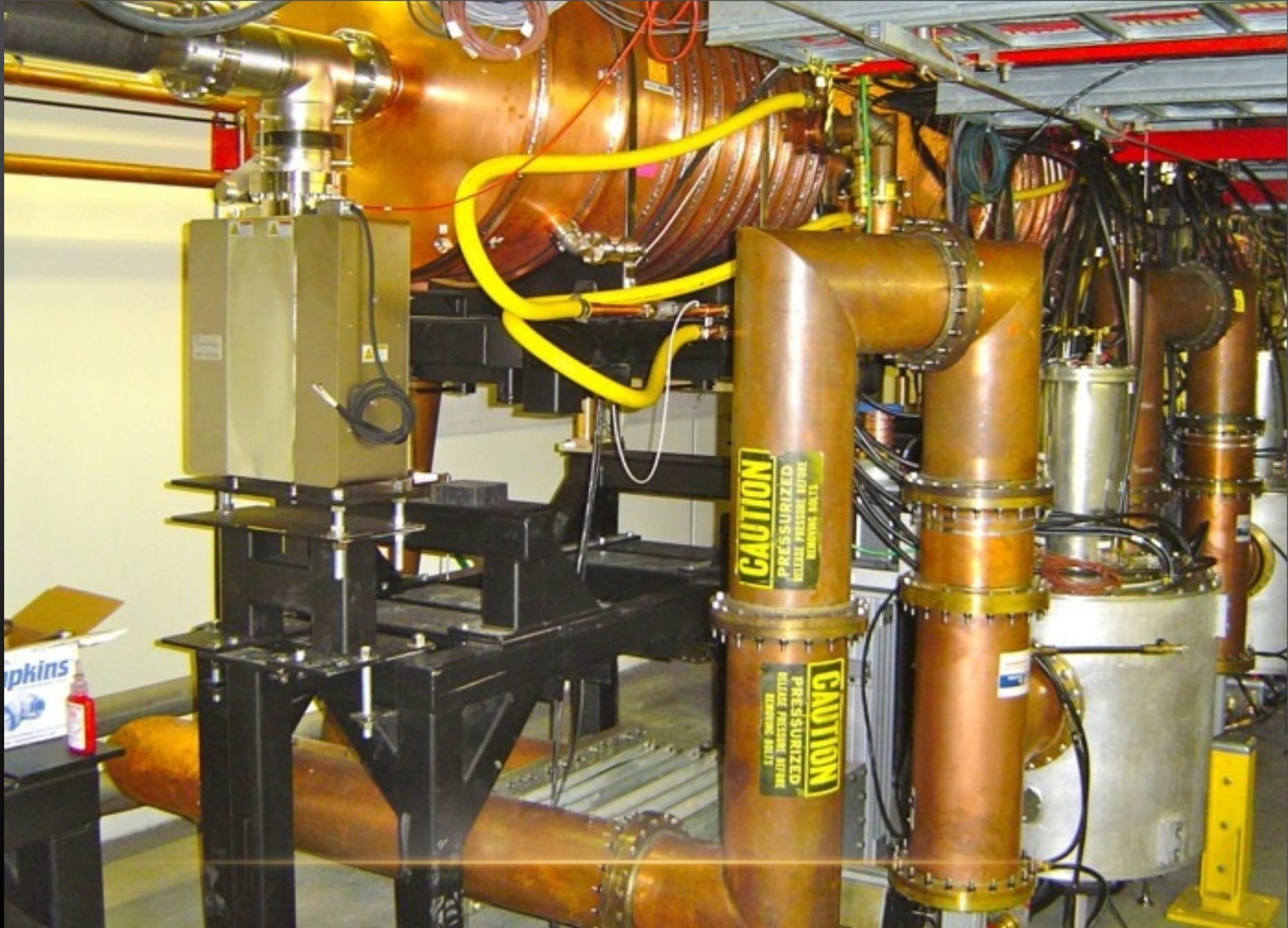
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Fermilab PAC 6-13- R. Dixon



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MI/RR Shutdown 2012

May 17th

MI-327 repairs:

Sump line repaired at multiple locations

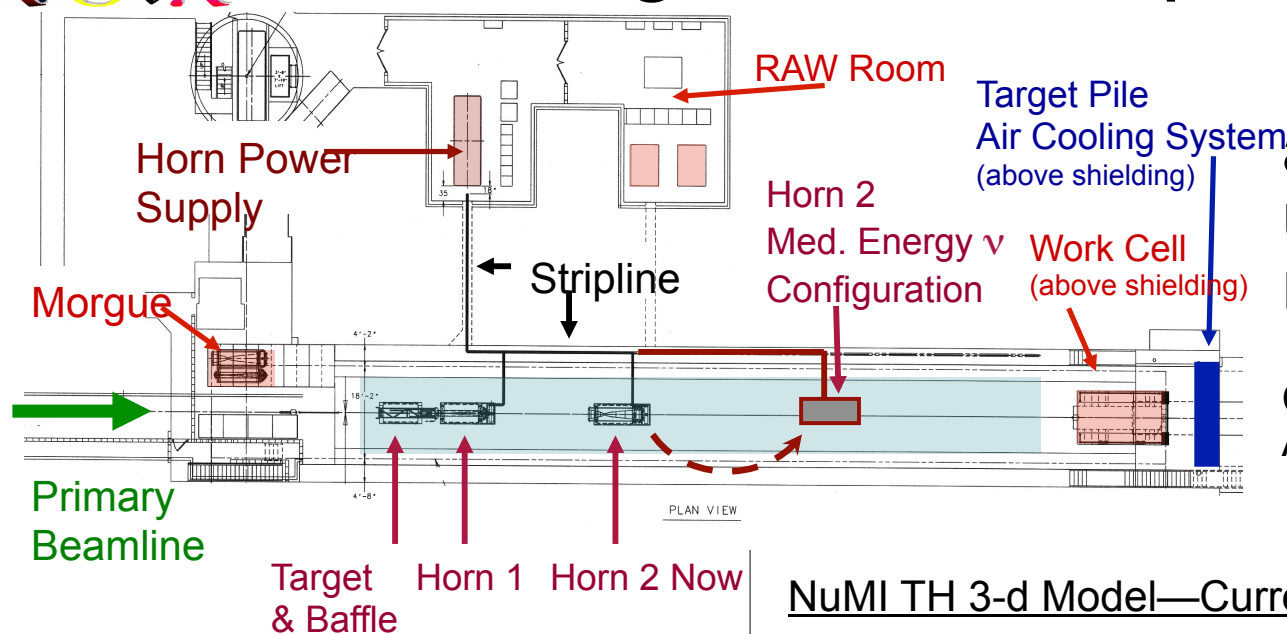
Conduit feeding power to ventilation fan has been replaced

Ventilation duct repaired





Target Hall: Scope of work

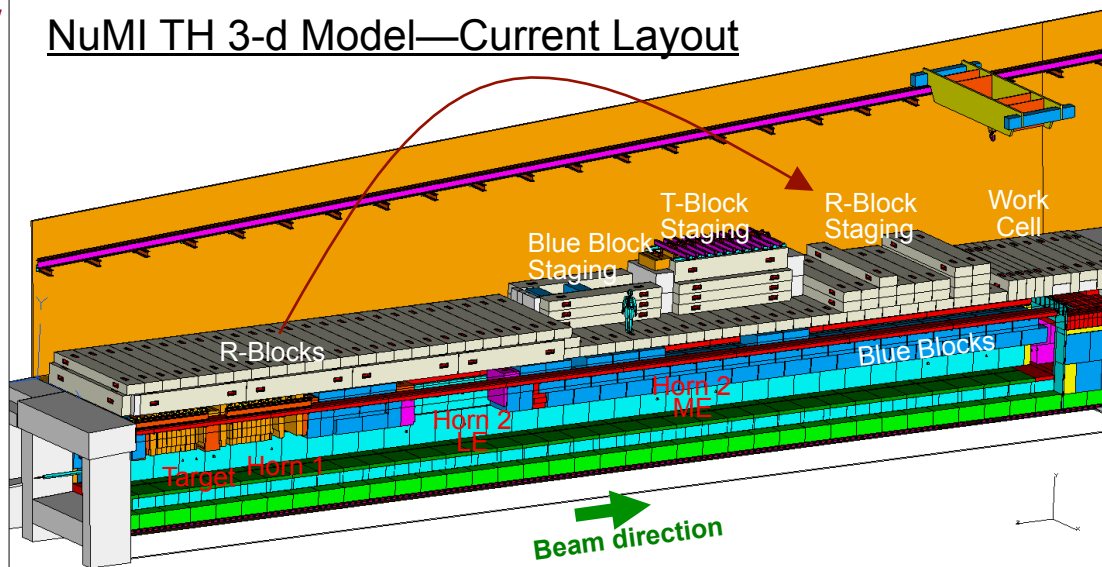


Utility work associated with upgrades: RAW most significant

Coordinated by Mike Andrews

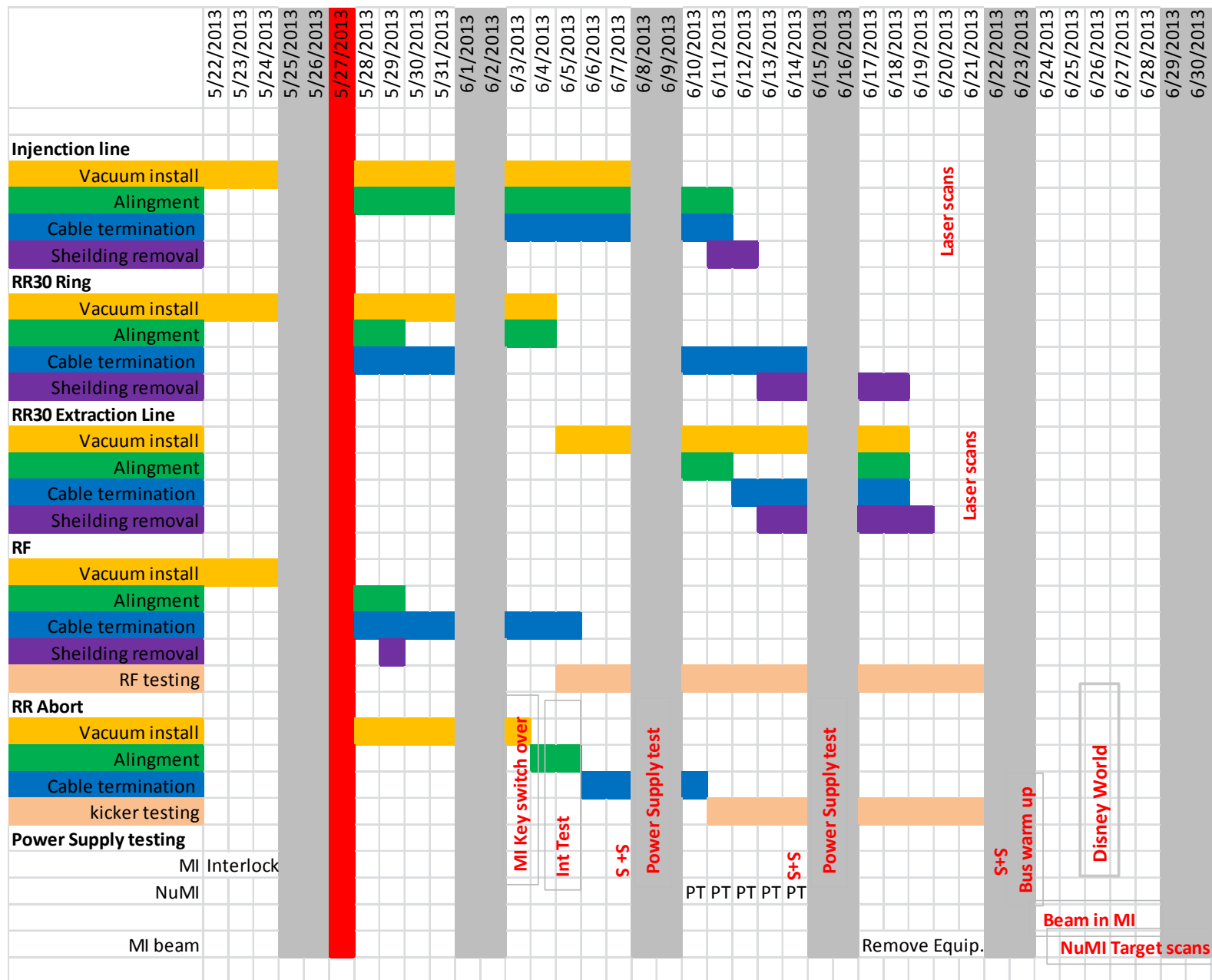
Limited space available for Target Hall activities (Horn 2 move, Target & Horn change outs & repairs, Radioactive Component Repair/Removal)

NuMI TH 3-d Model—Current Layout



Other NuMI Improvements

- Replaced 5 Quads for better cooling
- Installed cooling plates on 4 other quads
- Replaced 5 beam profile monitors
- Replaced Target Beryllium Window
- Installed LBNE prototype BPM



Remaining Issues

- End shims for Recycler Magnets
- Shielding for RF penetrations at MI60
- Kautz Road Substation lightening arrestors
- Infrastructure Maintenance
- Longer term issues due to PIP funding
 - Booster Cavity Refurbishment
 - Low Energy Klystron Developement

Week 1

- Establish MI Circulating beam and establish orbits.
- Accelerate MI beam to 120 GeV and measure orbits. Determine quad moves and move quads.
- Extract beam to NuMI target and start target scans.
- Start RR Injection line commissioning.

Week 2

- Extract beam to SY120.
- Start circulating beam studies. Establish working point.
- Start beam delivery to NuMI target with increasing intensities.
 - Non slipped stacked beam 1.7 sec MI cycle.
 - Can achieve up to 300 KW with nominal beam intensity from Booster.
 - Close to 100% efficiency
 - Only 3.5 Hz from Booster are required

Week 3

- Start RR 53 MHz commissioning.
- Start RR Instrumentation timing and commissioning.
- SY120 Studies
- Continue the beam delivery to NuMI target.

Week 4

- Start RR measurements
 - Measure momentum aperture.
 - Measure chromaticities
 - Tune and obits compensation
- Start RR extraction line commissioning.
- SY120 Studies
- Beam to NuMI target.

Weeks 5-9

- Start RR high intensity studies.
 - Beam scrubbing?
- Start RR Slip Stacking commissioning.
- SY120 beam commissioning with high intensity.
-

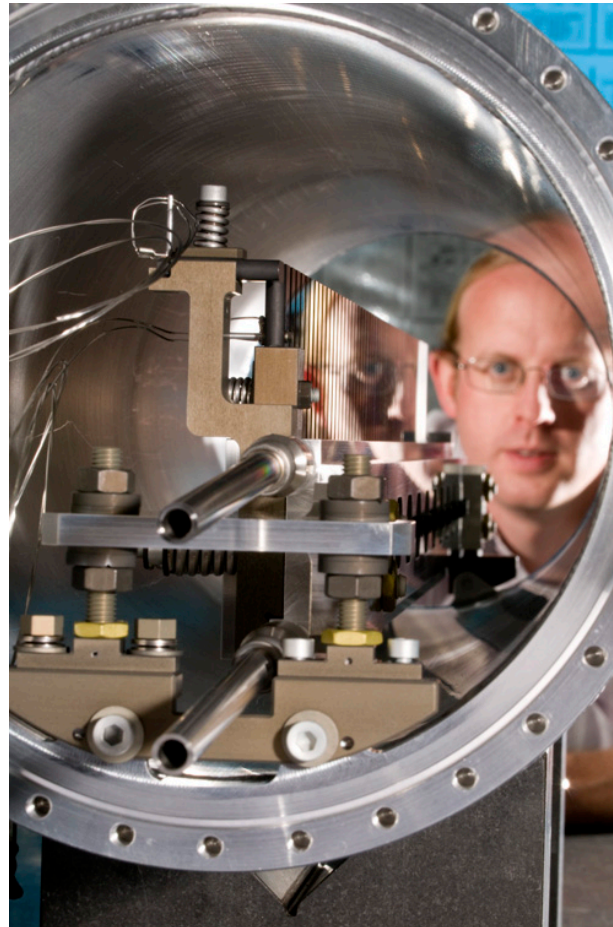
Summary

- Shutdown coming to a close
- Startup activities underway
- Good progress on ANU and NuMI
- PIP delays due to funding has long term implications
- Outlook good for neutrinos in the coming year in NOvA



Target

- Target fabrication in collaboration with RAL



Shipped May 3rd!

In customs at O'Hare

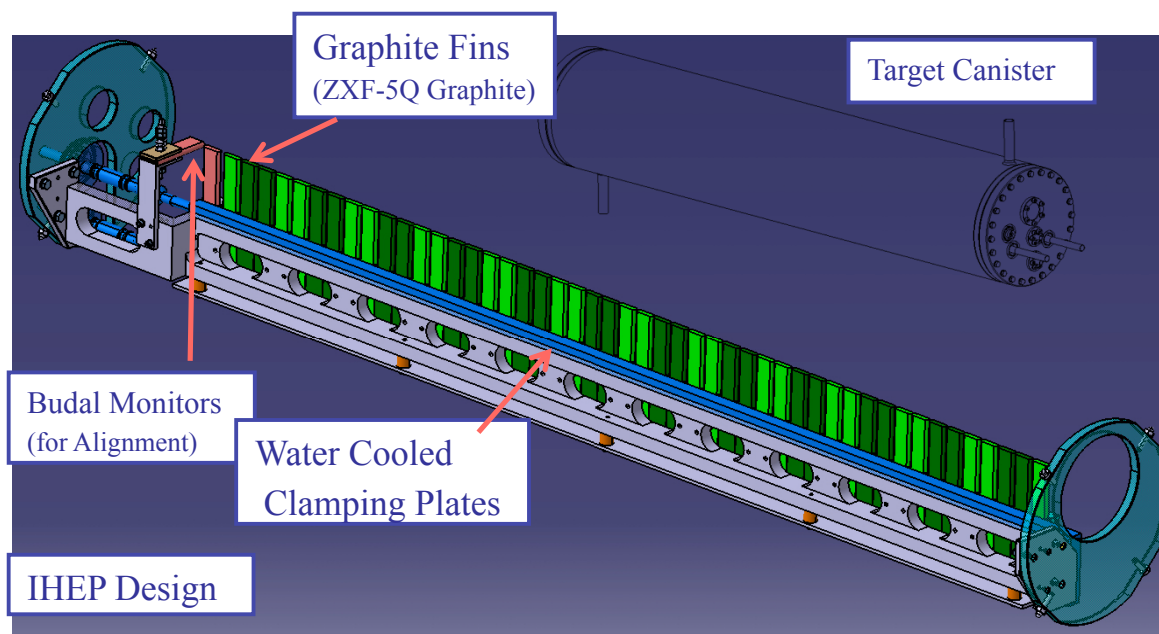
Mount on target
carrier by June 1

Ready for installation
by August 1



Target

- Target fabrication in collaboration with RAL



Summary

- Accelerator performance over the past year was good
- Proton Improvement Plan underway with budget reduction of 50% for the next year
- NOvA modifications to the MI and Recycler underway and on schedule so far
 - On schedule so far
- NuMI upgrades and reconfiguration going well
- Given the budget outlook, it will be quite a challenge to maintain our momentum

Roger,

The biggest change of course was the change of the NuMI Target Hall for NoVA running with the movement of the second horn and the installation of the 700 kW Horn 1 and 700 kW target. The shutdown went well and the changes are almost all done, and the performance of the systems at 700 kW is expected to be satisfactory. In addition much maintenance work was successfully implemented.

In SY120 two new areas were worked on: the High Rate Tracking area in M03 and a new test beam area in MCenter. AD has completed its work on the High Rate Tracking area. MCenter needs to have four magnets replaced and this will happen after the shutdown ends; the time estimate is a month since shielding blocks need to be taken out and then replaced. Also the shielding assessment is in progress for MCenter.

The Seaquest sleeving exercise is well underway and is expected to be complete in the early Fall. High intensity to the experiment is expected as a result of this change.

Craig

Major NuMI Shutdown Activities Completed

Mike Andrews

5/29/13

NuMI Beamline

Replace five Quad magnets with new cooling upgraded Quad magnets in MI (2) & Pre Target (3)
Installed cooling plates on four existing quad magnets & removed all cooling water flow restrictors
Replaced five Profile Monitors in MI (2) & Pre Target (3)
Replaced Target Beryllium window
Installed the LBNE BPM prototype in beamline downstream of Q121
Complete final survey of NuMI beamline

Target Hall

Relocated Horn 2 downstream in chase to the medium energy position
Replaced the Target & Horn 1 in chase
Completed Target Pile fan upgrades including installation of an additional cooling coil
Upgraded Target Hall dehumidification system
Rebuilt/repared the Target chase dehumidification system
Upgraded the MI65 RAW DI system for 700Kw operations
Upgraded Target, Horn 1, Horn 2, & Decay Pipe upstream RAW systems
Designed, fabricated, & installed MI65 RAW exchange system including controls system
Upgraded Horn pulse power supply
Drilled three 12' hydrostatic relief test holes in the east wall at entrance to Decay Pipe walkway
Repaired the concrete header at the rollup door entrance to Target Hall

Absorber Hall

Replaced Hadron Monitor

Upgraded Absorber, Intermediate, & Decay Pipe downstream RAW systems

Designed, fabricated, & installed Absorber Hall RAW exchange system including controls systems

Repaired & replaced ground control on the east wall of the emergency walkway

Individual tasks to be completed by June 14th

Complete installation infrastructure & controls for LBNE Muon Monitor prototype in Alcove 2

Complete installation PPD Muon Monitor system in Alcove 4

Complete safety interlock testing

Complete Horn pulse testing & thermal imaging of stripline

Complete power supply testing

Install Target Hall shielding wall

Move Target from chase to work cell for first phase of low intensity beam scans

Dry set R-blocks on chase over Target, Horn 1 & Horn 2

Complete low intensity beam scans of Horn 1 & 2

Install Target in chase for second phase of beam scans

Complete final survey of Target in chase

Complete low intensity beam scans of Target

Air seal all R-blocks on chase

Remove Target Hall crane electronics